AMENDMENTS TO THE DRAWINGS.

Applicant appends a replacement copy of FIG. 1 with the label "Prior Art" as requested by the Examiner.

Attachment: 1 Replacement Sheet (FIG. 1).

REMARKS

Status of the Claims

Claims 1-50, including eight independent claims (1, 7, 14, 23, 32, 33, 39, and 46), are pending in the present application. By this amendment, claims 2-4, 6, 8, 10, 14, 16, 19-21, 23, 30, 46, 49, and 50 are amended. Claim 31 has been canceled without prejudice. New claims 51-54 are presented. Reconsideration of claims 1-30 and 32-50 is respectfully requested, along with consideration of new claims 51-54.

Drawings

The Examiner has objected to the drawings under 37 CFR 1.83(a) stating that they do not show every feature of the claimed invention. In particular, the Examiner notes that the "amplitude modulated (AM) signal", as recited in claim 5, and "applies to the transformer logic a signal of fixed duty cycle during a period in which an FSK signal is not being transferred" as recited in claim 17, must be shown.

Applicants respond by pointing out that the objected-to recitations are reflected within the drawings of the application. With respect to the amplitude modulated signal, Applicants point to paragraph [0070] in the published application that states "[a]mplitude modulated device signals inductively transferred by the transformer 18" across the isolation barrier 20 are graphically depicted by wave 38b in the drawing [of FIG. 3]." With respect to claim 17, Applicants point to paragraph [0067] in the published application that states "the modulator 22 is set to a fixed duty cycle during periods when the control device 12 is not generating and transmitting control signals across the isolation barrier 20....[t]his signal is, of course, inductively transferred over the barrier 20 by the transformer 18'..." The reference symbols clearly refer to FIG. 2. Thus, FIGS. 2 and 3 show the features of claims 5 and 17.

Applicants append a replacement copy of FIG. 1, inserting the phrase "Prior Art," as requested by the Examiner.

Accordingly, by these remarks and the replacement copy of FIG. 1, Applicants believe the drawings comply with 37 C.F.R. §1.83(a).

Specification

Paragraph [0001] of the published application is amended to correct the typographical error pointed out my the Examiner. In addition, paragraphs [0059], [0066], and [0070] are also amended to further correct typographical errors noticed by the Applicant. As such, these corrections do not add new matter to the present application. Entry of these corrections is respectfully requested.

Claim Objections

The Examiner objected to claims 2, 4, 8-10, 12, 14-31, 49 and 50 because of various informalities. In particular, claims 2 (line 3), 4, 8, 10, 23, 30, 49, and 50 are amended as suggested by the Examiner to clarify the language of the claims.

With regard to the objection of claim 2, line 5, the claim is amended to recite "another analog FSK signal." As supported in paragraph [0064] of the published application, the demodulated PWM signal need not be identical to the original FSK signal.

With regard to the objection of claim 12, Applicant notes that the lack of a specific version of the standard signal format is not required. Indeed, any of the versions of the format that are compatible can be utilized.

With regard to the objection of claim 14, the claim is amended to recite "encoded therein another analog FSK signal." As supported in paragraph [0064] of the published application, the demodulated PWM signal need not be identical to the original FSK signal. Accordingly, claims 16, 19, 20, and 21 are amended to clarify antecedent bases.

In addition, claim 3 is amended to correct its dependency. Claim 6 is also amended to provide a correct antecedent basis for the modulator. Claim 14 is amended to correct the antecedent basis in the preamble. Claim 31 is canceled as being redundant in light of claim 23. Claim 46 is amended to remove repetitious language in the preamble, and to insert the word "and."

As such, none of the claim amendments adds new matter. With these amendments, Applicant believes the claims are in proper form for allowance.

Enablement of Claims 1-50

The Examiner currently rejects claims 1-50 under 35 U.S.C. 112, first paragraph, for failing to comply with the enablement requirement because "the specification does explain [] how 'an analog FSK signal' can be implemented." The claims, however, are enabled because the specification, combined with the knowledge of those skilled in the art, is sufficient to enable generation of an analog FSK signal as so recited in the claims.

Contrary to the statement in the Office Action that FSK signals as known in the art are generally digital signals, FSK signals typically frequency shift an analog carrier signal between known frequencies to convey digital data. As documented in Exhibit A, a paper explaining FSK signaling and modulation (FSK Demodulation: WJ Tech Notes 1980), FSK is a modulation scheme to send digital information "by shifting the frequency of a continuous carrier" (i.e., using an analog signal). Indeed, as stated in the published application at paragraph [0075], the FSK component "is traditionally but somewhat erroneously referred to as a 'digital' signal, but which shall continue to be referred to as an analog signal."

Furthermore, as noted in the published application at paragraph [0057], a digital control signal "is modulated to analog form...by modem 16'...By way of non-limiting example...the analog form is a frequency shift keying (FSK) signal defined by 'tones' in the range of 1-5 Htz range that are superimposed on a 4-20 mA current signal, in the manner of industry standard FoxComm™ and HART™ protocols." As such, it is clear that those skilled in the art would clearly know how to produce an analog FSK signal.

The Office Action itself provides support that those skilled in the art would recognize how to produce analog FSK signal as shown in the cited Feldman patent (U.S. Patent No. 6,295,272). The subchannel carrier signal 23, shown in FIG. 5 of Feldman as an analog signal, can be a "frequency-shifitkeyed [sic] subcarrier," as recognized in the Office Action (see item 8).

Accordingly, claims 1-50 are enabled with respect to 35 U.S.C. §112, first paragraph.

__Definiteness of Claim 6__

Claim 6 is currently rejected under 35 U.S.C. §112, second paragraph as being indefinite because of the recitation to an "aforesaid modulator." Claim 6 is amended to recite that "the AM signal utilizes a carrier generated by a fixed duty cycle output of a modulator for generating the PWM signal." Support for the amendment is found at paragraphs [0067] and [0068] of the published application. As such, amended claim 6 does not add new matter. The claim is definite under 35 U.S.C. §112, second paragraph.

__Nonobviousness__

A, Claims 1-4, 7-11, 13, 32-36 and 38: Combination of Harris, Feldman, and AARP

Claims 1-4, 7-11, 13, 32-36 and 38 are currently rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent No. 6,295,272 B1 to Feldman et al. (herein "Feldman") in view of U.S. Patent No. 4,897,854 to Harris et al. (herein "Harris") and Applicants' Admitted Prior Art (AAPA). The claims, however, are patentable because there is no suggestion or motivation to combine Feldman and Harris to teach the recitations of the pending claims.

1. Claims 1-4

Independent claim 1 is directed to an input/output circuit of a process control system having a transformer for generating an analog frequency shift keying (herein "FSK") signal across an isolation barrier. The improvement includes having the transferred FSK signal encoded in a pulse width modulated (herein "PWM") signal. As noted in the instant application, the circuit of claim 1 can help address communication between a field device and the remainder of a control system in which the field device is electrically isolated (see paragraph [0010] of the published application). When utilizing a transformer to transfer signals over an isolation barrier, the bandwidth limitations of the transformer can be an issue (see id., paragraph [0012]). By encoding FSK signals in PWM form before transfer over a transformer, smaller, less costly and less power-hungry transformers can be used than those needed to transfer FSK signal directly (see id., paragraph [0060]). Accordingly, the present application not only suggests the invention of claim 1, but provides motivation for practicing the claim.

In contrast, the cited art does not suggest the invention of claim 1. Feldman teaches techniques for implementing a subchannel on a *high speed data signal* for transmission on media shared between two high speed data nodes, hubs, or peripherals. In particular, Feldman teaches ways of creating a combined signal from a data-modulated subchannel carrier signal (e.g., frequency shift-keyed) and a high speed data signal (see Feldman, column 12, lines 9-41). Though the combining of signals tends to pulse width modulate the high speed data transitions, Feldman is completely void of any suggestion to utilize its combined signal with a transformer for transferring a PWM signal across an isolation barrier. Indeed, given the high speed data signal, Feldman only teaches using "shared media 20 (consisting of two pairs of conductors, one pair for each direction)" to achieve such high speed transfer rates.

Harris also fails to provide any suggestion for creating the circuit of claim 1. While Harris does teach pulse width modulating a serial NRZ data stream for communication in an environmentally hostile environment and using a transformer with a twisted pair network cable, but there is no suggestion of (i) utilizing a transformer to transmit over an isolation barrier; and (ii) encoding a FSK signal in a PWM signal for transmission over an isolation barrier by a transformer.

Furthermore, there is absolutely no motivation to combine the teachings of Feldman and Harris. Feldman's combined signal is a *data-intensive stream requiring high speed transfer* at a bit rate of about 1GB or faster (see id. at column 7, line 39). Since the combined is a data rich stream requiring high speed transmission (see id. at column 13, lines 3-10, noting that the subchannel data is about 200 kilobits/second, which can easily be accommodated over high speed protocols such as Ethernet with a maximum speed of 10 megabits/second), there is no motivation to encode an FSK signal in a PWM signal to enable a transformer to transmit a signal over an isolation barrier. If anything, Feldman suggests against using a transformer to replace the shared media connection because such a transformer would be very costly in terms of power and monetary consumption given the density of data to be transferred in the Feldman's combined signal. Harris also lacks any mention to motivate one to utilize a transformer to transmit a PWM signal encoding an analog FSK signal across an isolation barrier.

The Office Action's reference to Applicant's Admitted Prior Art (herein "AARP") also fails to provide the motivation to combine the teachings of Feldman and Harris. Though the present application states that "[t]ransformer-based isolation has several advantages [such as]

lower cost, durability, and reliability," the application also states that "*the bandwidth of the data transfers is limited – unless resort is had to unduly large transformers*. This can be problematic in applications where power or physical space are limited" (see paragraph [0012] of the published application, emphasis added). Because of the high-speed and data-dense requirements of Feldman, the statements of paragraph [0012], taken in total, would actually point away from combining Feldman with Harris since Harris is directed to low data transfer applications such as simple clock recovery.

Independent of any suggestion and motivation that exists to combine Harris and Feldman, the combination fails to render claim 1 obvious for at least two additional reasons. First, neither Harris nor Feldman teach the use of a transformer that generates a signal for transfer across an isolation barrier. As such, the cited art does not teach the recitations of claim 1. Second, combining the serial data transmission system of Harris to achieve the data transfer protocol suggested in Feldman results in an inoperable system. Since Feldman requires bit rates of 1GB or faster, such a data transmission requirement would overwhelm the system of Harris, which is configured for low data transmission applications such as simple clock recovery (see Harris, column 2, lines 51-53).

For all of these reasons, the combination of Harris and Feldman cannot render claim 1 obvious. Since claims 2-4 are all dependent from claim 1, they are also not obvious for at least the same reasons. In addition, claim 2 is not obvious because the cited art does not teach "a demodulator...that *converts* the PWM signal back into another analog FSK signal." Since the combined signal of Feldman inherently has FSK components, the combined signal is fed directly to an FSK receiver and converted to voltage variations on line (see Feldman, FIG. 18, and column 26, lines 41-55). As such, the FSK receiver does not *convert* the PWM signal back into another analog FSK signal. Harris also does not teach this feature. Claims 3 and 4 are also not obvious because neither Feldman nor Harris apply their systems to "a workstation, field controller, field device, smart field device, or other device for process control." Though the Office Action suggests such devices are taught by Feldman, the reference to Feldman, column 1, lines 30-32, only refers to entire computer systems and control data management devices, not to the specific devices recited in claims 3 and 4.

2. Claims 7-11 and 13

Independent claim 7 is drawn to isolation logic for use in transferring information over a transformer between control devices. The logic includes a modulator that generates a PWM signal encoding an analog FSK signal to be transferred. As such, claim 7 is not obvious in light of Feldman, Harris, and the alleged AARP for substantially the same reasons that claim 1 is not obvious, as discussed earlier (i.e., none of the cited art suggests or motivates generating a PWM signal encoding an analog FSK signal to be transferred over a transformer). Claims 8-11 and 13 depend from claim 7, and are also not obvious for at least the same reasons. Claim 11 is also not obvious for the reasons that claim 2 is not obvious, i.e., the cited art does not teach the recited devices. Claim 13 is also not obvious since none of Harris, Feldman, or the alleged AARP mention or suggest galvanic isolation as recited in the claim.

3. Claim 32

Independent claim 32 is directed to a method of operating a process control system having a transformer that transfers an analog FSK signal across an isolation barrier, wherein the FSK signal is encoded in a PWM signal. As such, the claim is not obvious in light of Feldman, Harris, and the alleged AARP for substantially the same reasons that claim 1 is not obvious.

4. Claim 33-36 and 38

Independent claim 33 is directed to a method of transferring an analog FSK signal over a transformer between control devices. The steps of the method include generating a PWM signal encoding a FSK signal to be transferred, and applying the PWM signal to the transformer. As such, claim 33 is not obvious for the substantially same reasons that claim 1 is not obvious. Claims 34, 35, 36, and 38, depending from claim 1, are accordingly not obvious for at least the same reasons that claim 33 is not obvious. In addition, claims 34 and 35 are not obvious for the same reasons that claim 2 is not obvious, claim 36 is not obvious for the same reason that claim 3 is not obvious, and claim 38 is not obvious for the same reason that claim 13 is not obvious.

Accordingly, claims 1-4, 7-11, 13, 32-36, and 38 are all patentable over Harris, Feldman, and the alleged AARP.

B. Claims 5, 6, 14-20, 22, 23-29, 31, 39-43, 45, 48, and 50: Combination of Feldman, Harris, AARP and Saeki

Claims 5, 6, 14-20, 22, 23-29, 31, 39-43, 45-48, and 50 are currently rejected under 35 U.S.C. 103(a) as being unpatentable over Feldman in view of Harris and AAPA and in further view of U.S. Patent No. 4,899,158 to Saeki et al. (herein "Saeki"). The claims, however, are not obvious because the cited art neither suggests nor motivates the claimed invention.

1. Claims 5 and 6

Claims 5 and 6, each dependent from claim 1, are not obvious in light of Feldman, Harris, and the alleged AARP for the same reasons for that claim 1 is not obvious, i.e., none of the sources teaches, suggests, or motivates generating an analog FSK encoded in a PWM signal that is transferred over an isolation barrier with a tranformer. Saeki also fails to provide the necessary suggestion or motivation to practice claim 1. Saeki is directed to a moving object discriminating system that includes an interrogator utilizing a FSK modulator to produce a FSK signal that can be AM modulated before being sent to an antenna for transmission (see Saeki, column 3, lines 1-17). The reference has no bearing on the problem of transmitting FSK signals over an isolation barrier using a transformer. Thus, while Saeki teaches coupling a FSK modulator and AM modulator, the reference is absolutely void of any suggestion or motivation for utilizing these with a transformer to transmit over an isolation barrier or to combine these with a PWM signal that encodes a FSK signal. Though the Office Action suggests that one would combine Saeki with Feldman to increase data rate transfer, the citation to Saeki only shows that data can be transferred with Saeki's antenna system. There is absolutely no hint or suggestion that Saeki's AM technique can be advantageously utilized with a transformer to send a PWM signal that encodes an FSK signal. Indeed, the only place that motivates the practice of the claims is the present application. Accordingly, Saeki's teachings do not help bridge the teaching gap to teach claim 1. As such, claims 5 and 6 are not also obvious in light of Feldman, Harris, the alleged AARP, and Saeki.

2. Claims 14-20 and 22

Independent claim 14 is directed to an input/output module for use in industrial, manufacturing, service, environmental or process control to transfer information over an isolation barrier between control devices. The module comprises transformer logic that inductively transfers a PWM signal having encoded therein an analog FSK signal across the

isolation barrier from a first control device to a second. The transformer logic also inductively transfers an AM signal across the isolation barrier, the AM signal encoding another analog FSK signal to be transferred from the second control device to the first. As discussed above, the combination of Feldman, Harris, the alleged AARP and Saeki does not suggest or motivate one to utilize transformer logic that inductively transfers a PWM signal, having encoded therein an analog FSK signal, across an isolation barrier from a first control device to a second device. Nor does the combination suggest coupling such logic with further logic that transfers an AM signal from the second device to the first that encodes another FSK signal. Accordingly, claim 14 is not obvious. Since claims 15-20 and 22 all depend from claim 14, the claims are also not obvious for at least the same reasons. In particular, the Office Action states that claim 17 is obvious since Applicant has not disclosed an advantage of not transferring a FSK signal. On the contrary, paragraphs [0067] and [0068] of the published application, with reference to FIG. 3, describe that the first modulator can generate a signal with fixed duty cycle to produce a carrier wave on the field side to be modulated and sent back to the control side. There is no teaching, suggestion, or motivation in any of the cited art to practice the subject matter of claim 17. With regard to claim 22, Feldman does not teach that the control devices can be any of a workstation, field controller, field device, smart field device, or other device for any of industrial, manufacturing, service, environmental, or process control, as discussed earlier. Indeed, Feldman's high data density systems are only used with large computer systems that require high speed, large throughput and large bandwidth since huge amounts of information are being processed (see Feldman, column 1, lines 20-30).

3. Claims 23-29 and 31

Independent claim 23 is directed to a control system that includes a first analog source that generates a first FSK signal and a first modulator coupled to the first analog source for generating a PWM signal that encodes the first FSK signal to transfer information between a first control device and a second control device. As such, the combination of Feldman, Harris, the alleged AARP and Saeki cannot render claim 23 obvious, independent of the other recitations of the claim, because there is no suggestion or motivation to in the cited art to arrange the recited elements of claim 23 at least for the reasons discussed earlier with respect to claim 5. Since claims 24-29 all depend from claim 23, they are also not obvious for at least the same reasons that claim 23 is not obvious. As discussed above, claim 31 is canceled.

4. Claims 39-43 and 45

Independent claim 39 is drawn to a method for transferring information over an isolation barrier between first and second control devices. The method includes inductively transferring a PWM signal across the isolation barrier, the PWM signal having encoded therein an analog FSK signal. Accordingly, the combination of Feldman, Harris, the alleged AARP, and Saeki cannot render claim 39 obvious because there is no suggestion or motivation to in the cited art to practice the recited step of the method, as discussed earlier with respect to claim 5. Claims 40-43 and 45 depend from claim 39, and are also not obvious for at least the same reasons that claim 39 is not obvious.

5. Claims 46-48 and 50

Independent claim 46 is drawn to a method of operating a control system. The method includes generating a PWM signal having encoded therein a first FSK signal. Accordingly, the combination of Feldman, Harris, and Saeki cannot render claim 46 obvious because there is no suggestion or motivation to in the cited art to practice the recited step of the method, as discussed earlier with respect to claim 5. Claims 47, 48, and 50 are also not obvious in light of the cited art for at least the same reasons that claim 46 is not obvious since the claims all depend from claim 46.

C. Claims 12 and 37: Combination of Feldman, Harris, AARP, and Anderson

Claims 12 and 37 are currently rejected under 35 U.S.C. 103(a) as being unpatentable over Feldman in view of Harris and AAPA and in further view of U.S. Patent No. 6.297,691 B1 to Anderson et al. (herein "Anderson"). The claims, however, are not obvious because the cited art neither suggests nor motivates either claim. Claim 12 is dependent from claim 7. As such, claim 12 is not obvious in light of Feldman, Harris, and the alleged AARP at least for the reasons that claim 7 is not obvious. Anderson fails to provide adequate teaching, along with Feldman and Harris, to practice claim 12. Though Anderson reveals the use of the HART system to transmit FSK signals, such teaching is in the context of a system that modulates and demodulates signals between a coherent and non-coherent signal protocol. Anderson is completely void of any mention, suggestion, or hint of a modulator that generates a PWM signal encoding an analog FSK signal to be transferred between control devices. As such, the reference

fails to provide the suggestion or motivation lacking in Feldman and Harris to practice claim 7. Accordingly, Anderson's teachings still fall short in being able to render dependent claim 12 obvious, despite its mention of the HART system. Claim 37, dependent from claim 33, is also not obvious for at least the same reasons as stated with respect to claim 12.

D. *Claims 21, 30, 44, and 49: Combination of Feldman, Harris, AARP, Saeki, and Anderson*

Claims 21, 30, 44, and 49 are currently rejected under 35 U.S.C. 103(a) as being unpatentable over Feldman in view of Harris and AAPA and in further view of Saeki and Anderson. As discussed above, however, none of the cited art provides the suggestion or motivation for practicing any of the corresponding independent claims from which the currently rejected claims depend (i.e., independent claims 14, 23, 39, and 46, respectively). Accordingly, each of claims 21, 30, 44, and 49 are patentable over the cited art.

New Claims 51-54

New claims 51-54 are presented. New claim 51, dependent from claim 1, recites that "the FSK signal is converted to the PWM signal before being transferred by the transformer." Support for the claim is found at paragraph [0058] of the published application (stating that "[p]ulse width modulator 22 converts the FSK control signal to a pulse width modulated (PWM) form"). As such, the claim does not add new matter. Accordingly, claim 51 is patentable for at least the same reasons that claim 1 is patentable. Claim 51 is further distinguished from the combined teachings of Feldman and Harris in that neither Feldman nor Harris teach *converting* a FSK signal to a PWM signal. Though Feldman discusses *combining* a high speed data signal with a subchannel signal, the reference *does not discuss converting* a FSK signal to a PWM signal. As stated in Feldman, the "combined signal has *both amplitude variations* caused by the addition of the subchannel carrier *and also has pulse width modulation* caused by perturbation of the zero crossing times of the leading and trailing edges of the high speed data transitions" (see Feldman, column 12, lines 11-15, emphasis added). Accordingly, Feldman does not disclose converting of a FSK signal to a PWM signal. Thus, the combination of Feldman and Harris do not teach the recitations of claim 51, and cannot render the claim obvious.

New claims 52-54 also include recitations related to converting a FSK signal to a PWM signal. As such, the claims are also not obvious in light of Feldman and Harris for at least the same reasons stated for claim 51.

Consideration and allowance of new claims 51-54 is respectfully requested.

CONCLUSION

In view of the amendments and remarks above, Applicant submits that claims 1-30 and 32-54 are in condition for allowance, and allowance thereof is respectfully requested. Applicant encourages the Examiner to telephone the undersigned in the event that such communication might expedite prosecution of this matter.

Dated: March 29, 2006

Respectfully submitted,

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Exhibit A

Watkins-Johnson Company
Tech-notes

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FSK: Signals and Demodulation

Frequency shift keying (FSK) is the most common form of digital modulation in the high-frequency radio spectrum, and has important applications in telephone circuits. This article provides a general tutorial on FSK in its many forms. Both modulation and demodulation schemes will be discussed

Binary FSK

Binary FSK (usually referred to simply as FSK) is a modulation scheme typically used to send digital information between digital equipment such as teleprinters and computers. The data are transmitted by shifting the frequency of a continuous carrier in a binary manner to one or the other of two discrete frequencies. One frequency is designated as the "mark" frequency and the other as the "space" frequency. The mark and space correspond to binary one and zero, respectively. By convention, mark corresponds to the higher radio frequency. Figure 1 shows the relationship between the data and the transmitted signal.

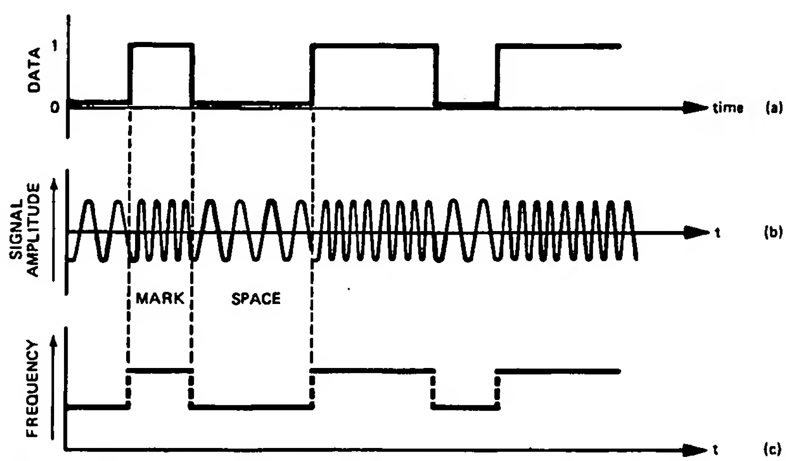


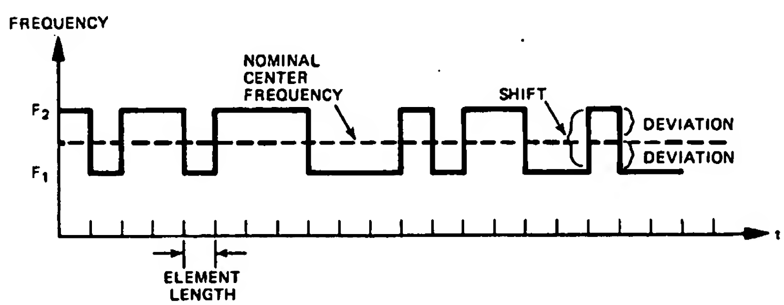
Figure 1. FSK modulation. Binary data (a) frequency modulates the carrier to produce the FSK signal (b) which has the frequency characteristic (c).

The most commonly used signal parameters for describing an FSK signal are shown in Figure 2. The minimum duration of a mark or space condition is called the element length. Typical values for element length are between 5 and 22 milliseconds, but element lengths of less than 1 microsecond and greater than 1 second have been used. Bandwidth constraints in telephone channels and signal propagation considerations in HF channels generally require the element length to be greater than

0.5 millisecond. An alternate way of specifying element length is in terms of the keying speed. The keying speed in "bauds" is equal to the inverse of the element length in seconds. For example, an element length of 20 milliseconds (.02 seconds) is equivalent to a 50-baud keying speed.

Frequency measurements of the FSK signal are usually stated in terms of "shift" and center frequency. The shift is the frequency difference between the mark and space frequencies. Shifts are usually in the range of 50 to 1000 Hertz. The nominal center frequency is halfway between the mark and space frequencies. Occasionally the FM term "deviation" is used. The deviation is equal to the absolute value of the difference between the center frequency and the mark or space frequencies. The deviation is also equal, numerically, to one-half of the shift.

FSK can be transmitted coherently or noncoherently. Coherency implies that the phase of each mark or space tone has a fixed phase relationship with respect to a reference. This is similar to generating an FSK signal by switching between two fixed-frequency oscillators to produce the mark and space frequencies. While this method is sometimes used, the constraint that transitions from mark to space and vice versa must be phase continuous ("glitch" free) requires that the shift and keying rate be interrelated. A synchronous FSK signal which has a shift in Hertz equal to an exact integral multiple (n = 1, 2,...) of the keying rate in bauds, is the most common form of coherent FSK. Coherent FSK is capable of superior error performance but noncoherent FSK is simpler to generate and is used for the majority of FSK transmissions. Noncoherent FSK has no special phase relationship between consecutive elements, and, in general, the phase varies randomly.



$$\text{SHIFT} = |F_2 - F_1|$$

$$\text{CTR FREQ} = \frac{F_2 + F_1}{2}$$

$$\text{DEVIATION} = \frac{\text{SHIFT}}{2} = \left|\frac{F_2 - F_1}{2}\right|$$

$$\text{KEYING SPEED IN BAUDS} = \frac{1}{\text{ELEMENT LENGTH (IN SECONDS)}}$$

Figure 2. FSK parameters.

Many different coding schemes are used to transmit data with FSK. They can be classified into two major groups: synchronous and asynchronous. Synchronous transmissions have mark-to-space and space-to-mark transitions in synchronism with a reference clock. Asynchronous signals do not require a reference clock but instead rely on special bit patterns to control timing during decoding. Figure 3 compares

synchronous and asynchronous keying.

A very common asynchronous coding system is the 5-bit Baudot code with leading start (release) and trailing stop (latch) elements. Originally designed for use with mechanical teleprinters, the system is "latched" until a "release" element is received, causing the printer to interpret the next 5 element intervals as code bits. The binary values of the 5 bits correspond to a particular character. In Figure 4, the two character patterns correspond to the characters "C" and "W" respectively. The 5 "information" bits are immediately followed by a stop or "latch" bit lasting a minimum of 1.42 element lengths. The latch bit stops the printing decoder until the decoder is again started by the next "release" element. The length of the latch bit may be very long between characters, especially in the case of manually generated characters where the operator types more slowly than the system can transmit characters. The noninteger minimum latch element length of 142 elements and the random nature of manual character generation emphasizes the asynchronous nature of this scheme.

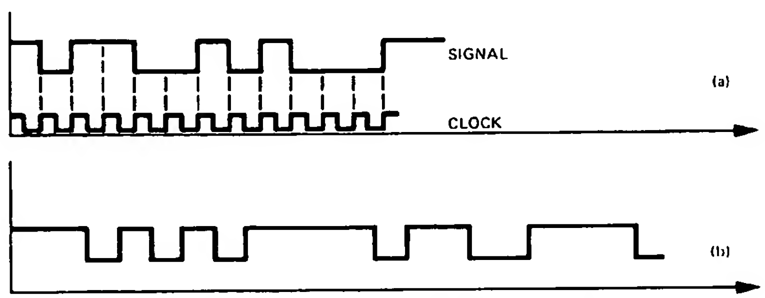


Figure 3. Synchronous (a) and asynchronous (b) signals.

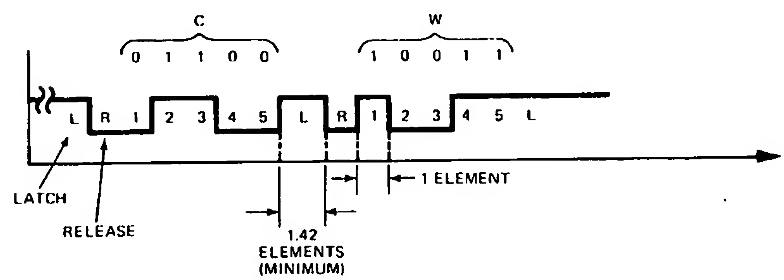


Figure 4. Baudot coded start-stop system (typical).

A common synchronous system uses Moore ARQ coding. The Moore code is a 7-bit-per-character code with no start or stop elements. Bit synchronization is maintained by using a reference clock which tracks the keying speed of the received signal. Character synchronization is maintained by sending periodic "idle" or "dummy" characters between valid data characters.